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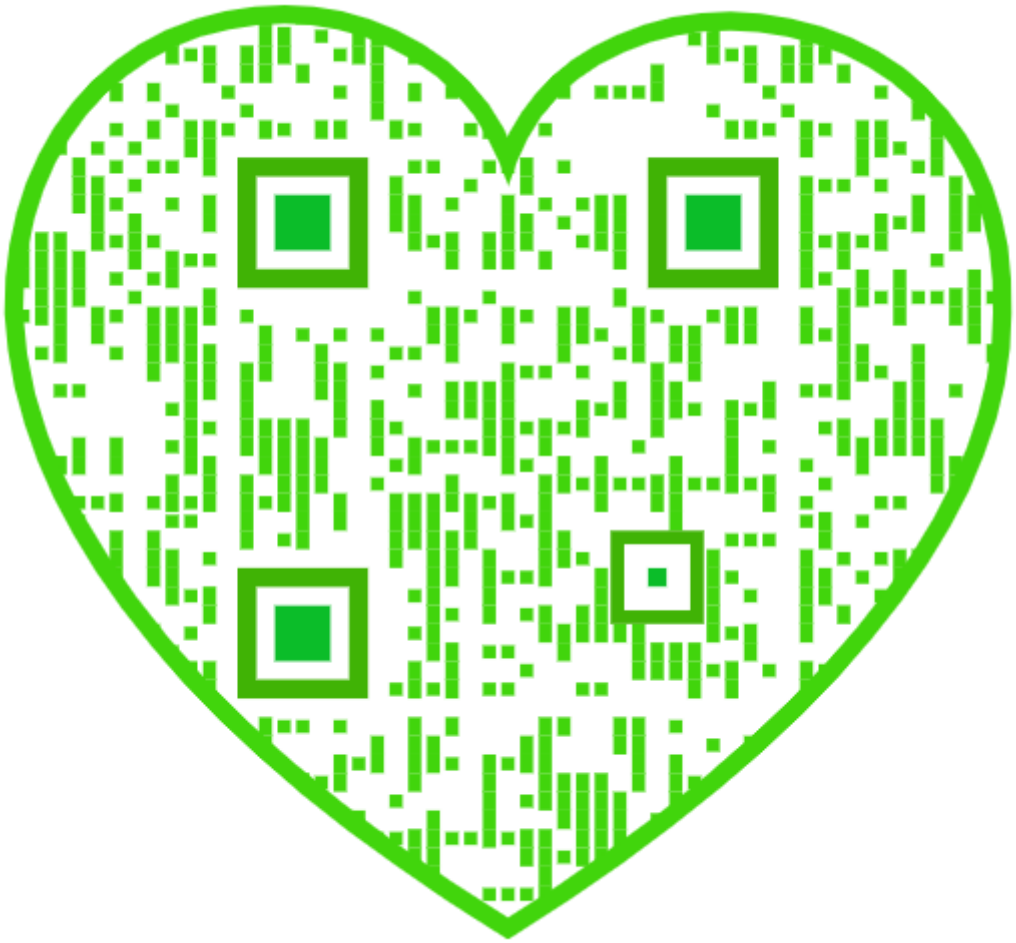

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PREFACE.

SURELY the Tercentenary of the Telescope should not be allowed to go by without some attempt to place before the public a concise account of that epoch-making instrument! The following is such an attempt—the expansion of a paper read before the Astronomical Society of Wales. It is hoped that the carefully-compiled lists which have been added may be of interest, and possibly of use. I am greatly indebted to Mr. Denning for kindly looking over the proofs, and to Mr. J. M. Staniforth for the frontispiece.

A. M.

The Story of the Telescope.

IT is exactly 300 years ago since a curious incident occurred at Middleburg in Holland. There lived in the town a spectacle-maker of the name of Lippershay. One day an apprentice was amusing himself with some of the spectacle-maker's glasses. Suddenly he so arranged the lenses that the weather-cock of a neighbouring church viewed through them seemed quite near and large. The apprentice was delighted, and told his master, and Lippershay, repeating the experiment, constructed

THE FIRST TELESCOPE.

Such is the story told of the invention of one of the most epoch-making of scientific instruments. The wonder is, however, that it had not been discovered before. Magnifying glasses had been in use from quite an early period. Friar Roger Bacon—that mighty thinker of the thirteenth century—says something in his works which looks as though he were aware of the principle of the telescope, and others had made guesses in a similar direction. However that may be, we cannot be absolutely sure that any such instrument was constructed before the beginning of the seventeenth century.

Like the astute Dutchman he was, Lippershay was not slow in turning his apprentice's discovery to practical account. He approached

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the Government and applied for a patent. But the Government treated him scurvily. It first took care to possess itself of the fruits of Lippershay's discovery, and then refused him the patent on the ground that a rival optician, named Jansen, knew all about the invention. Not the first time, nor far from the last, for a scientific discoverer to be shabbily treated by persons in authority.

Although the telescope came originally from the Netherlands, there is no proof that its discoverers applied it to the observation of the heavens. What we learn is that it was regarded as an instrument capable of achieving great things on the battlefield. For a general to be able to discern afar off the doings and movements of his enemy was a nobler achievement than to penetrate the secrets of the universe.

The invention of course was soon noised abroad, and the following year

GALILEO

in Italy, and Thomas Harriot in England heard of it. Harriot sent for specimens; Galileo does not seem to have done this, but some idea of the principle having reached him, he set his mighty brain to work, and constructed a similar telescope. These primitive instruments consisted of an object-glass and a concave eye-piece, a type which has since been known as the Galilean, and is confined to-day to small spy-glasses and binoculars. It may be added, by the way, that Lippershay h'm-

self constructed one or two glasses on the binocular principle. The price of these is stated to have been about £75 apiece!

It is not my intention here to tell the story of "the starry Galileo and his woes," which last were so largely brought about by the use of the instrument that has earned him his chief title to immortal fame. The great Florentine philosopher had no sooner made his first telescope, magnifying about three times, than he applied it to the observation of the heavens. What he saw astonished him so much that he set himself with ingenuity and patience to the perfection of the instrument until he had made one that magnified objects about thirty times—that is to say, it apparently brought them thirty times nearer and made them look thirty times larger than when viewed with the naked eye.

It is popularly thought that Galileo made his discoveries in rapid succession, turning from the Moon to Jupiter, from Jupiter to Saturn, and thence to the fixed stars, making discoveries as he did so. But his real progress was slower than that. His telescopes, the best of them, were feeble and imperfect, and he was opening up fresh ground, treading with difficulty where the fortunate student to-day treads with ease. Nevertheless, within three years of constructing his first telescope, he had discovered in the following order, the mountains of the Moon, additional stars in the Pleiades and elsewhere, four satellites of Jupiter, the phases of Venus

and the spots on the Sun, and had also glimpsed the ring of Saturn though he failed to discern its real form.

The astounding nature of these discoveries, coupled with their bearing on the received ideas of the cosmos, and, more than all, Galileo's impetuous way of putting forward his views—for the old philosopher wielded on occasion a terribly bitter and sarcastic pen—brought him into conflict with the authorities of the Church, a conflict ending in a persecution which no one to-day, whatever his views or creed, regards save with profound regret. Although Galileo was not tortured, perhaps never even threatened with torture, there is n doubt that he was pursued and harried to his grave, and his name must ever shine as a

MARTYR OF SCIENCE.

It must not, however, be forgotten that his persecutors acted in good faith, and in accordance with the temper of the age, and that by no means all even of the Churchmen of his epoch were opposed to him or his deductions. He and his friends were in the minority, and there was no mercy for minorities in those days.

Whilst Galileo was making his discoveries, other philosophers were not idle. In England

THOMAS HARRIOT

—who may be described as the most eminent scientific man at that time in

these islands—was busy experimenting with the new instrument. When in America twenty years before he had made use of a "perspective glass," and there are those who even claim him as an independent inventor of the telescope, whilst he certainly discovered the sun spots about the same time as Galileo himself. What he did first of all in the way of astronomical observation was done quite on his own initiative, and he therefore deserves far more honour in this connection than he has hitherto received.

With Harriot we must mention his friends, Sir William Lower and Thomas Protheroe, two gentlemen of means in West Carmarthenshire, who shared with him in these early labours. I have attempted elsewhere to tell the interesting story of their telescopic work;* but in order to make clear the position of both Harriot, Lower and Protheroe in reference to Galileo and other Continental workers, it may not be amiss to throw a few facts into chronological order as follows:—

1608

Oct. Lippershay of Middleburg in Holland constructs the first telescope. Jansen and Metius also claim the discovery.

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* See articles of mine in "Knowledge," December, 1908, and "The Nationalist" (Cardiff), October, in the same year.

1609

June. Galileo in Italy hears of Lippershay's discovery, makes experiments, and constructs a telescope on the principle which bears his name.

Aug. Galileo makes a somewhat more powerful instrument, with which he observes the Moon, Pleiades, Milky Way, &c.

Autumn. Harriot in England hears of Lippershay's discovery, procures specimens of the Dutch instruments, and sends one to Sir William Lower in Carmarthenshire; he also observes the Moon and makes a rough map of it.

1610

Jan. Galileo with a still larger instrument discovers Jupiter's moons. Simon Mayer sees the moons independently at Anspach. Lower and Protheroe observe the Moon, &c., in Carmarthenshire, and the former (Feb. 6) writes Harriot warning him that he may be forestalled in his discoveries, &c., if he does not take steps.

March. Galileo publishes his "Sidereus Nuncius" announcing his discoveries.

June. Lower writes to Harriot describing his observations, and asking for more telescopes and for a copy of Galileo's book.

July. Galileo observes imperfectly the ring of Saturn.

Oct. Galileo discovers the phases of Venus. Harriot observes Jupiter's moons.

Nov. Galileo discovers spots on the Sun.

Dec. Harriot does the same thing independently. (Rigaud says Dec., 1611.)

1611

March. Father Scheiner of Ingoldstat discovers the Sunspots independently.

June. Fabricius in Holland announces his discovery of Sunspots.

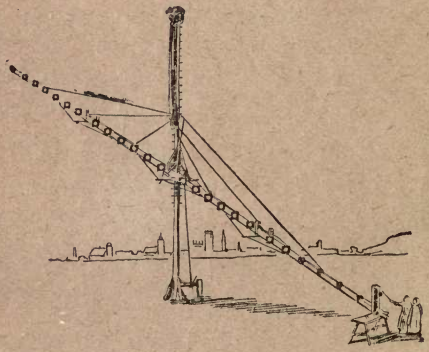
1612

May. Galileo announces his observations of Sunspots (begun in 1610).

A careful examination of this record will show that Harriot was well in the running with Galileo, and it is quite possible that, but for his modesty and delicate health, he might even have anticipated him. We need not, therefore, have any hesitation in giving Harriot every honour for his independent work, whilst Welshmen may feel a pardonable pride in the enthusiastic labours of Lower and Protheroe.

Grant, in his classic "History of Physical Astronomy," has done good work in showing that the first Dutch and English telescopes were not mere toys when compared with those of Galileo. To this end he refers to the observations of Harriot and Lower, and also quotes a letter written by Sir Christopher Heyden to Camden, the antiquary in July,

1610, in which Heyden says: "With one of our ordinary trunks I have told eleven stars in the Pleiades." "There can be no doubt (adds Grant) that the expression 'one of our ordinary trunks' refers to the Dutch telescopes which were in common use in England as distinguished from the superior telescopes of Galileo recently imported from Italy." Even had Galileo never taken up the matter "the Dutch telescopes would have been gradually perfected in their construction, and would have been eventually applied with success to the great purposes of physical science."



A 17TH CENTURY REFRACTOR.

Now that we have sketched very briefly the origin of the Telescope a word may be said on the

PRINCIPLE OF ITS CONSTRUCTION.

Everyone knows that objects look larger the

nearer they are brought to the eye. Place a coin a few yards away. Walk towards it. The coin will seem to grow larger and larger. But at a distance of less than a foot or so from the eye the coin, though growing still larger, will begin to look blurred and indistinct, hence bringing it nearer will be attended with no advantage. If, now, you place a lens of short focal length between the coin and your eye the blurring will be removed, and you will see the object perfectly clear and considerably magnified. This is, very roughly, the principle of the Microscope which is simply a means of seeing clearly an object brought very close to the eye.

But how are we to magnify a distant object, like a mountain or the moon? It is obvious that we must first obtain an image of the object, and then deal with that image as we did with our coin in the first illustration. A lens of fairly long focal length will give us the image we require, and the longer that focal length the larger will be the image at our disposal. Indeed, a lens with a focus of a few feet forms by itself a species of telescope which, though of feeble power, is better than the naked eye. Now, then, that we have got our image through the long focus lens, we can apply to it a short focus lens as we did to the coin above, the result being, when the lenses are properly adjusted, a more or less magnified image of the mountain or of the moon. This of course is only the very crudest idea of the process; but there are

plenty of text books going as deeply as you like into the subject.

The lens of long focus next the object is known as the object-glass. The lens of short focus next to the eye is called the eye-piece, and in the ordinary astronomical telescope—or Refractor, as it is called —the focal length of the object-glass divided by that of the eye-piece gives the magnifying power. Thus, if the object-lens gives at three feet a clear, sharp image of the sun, and the eye-piece does so at the distance of one inch, the resultant magnifying power is 36. It is very easy in this way to construct a rough telescope, and one can so be made for a shilling or two, that will show sunspots, the mountains of the moon, Jupiter's satellites, and other things. It will be but a primitive contrivance; still much better than nothing, and a step in the right direction.

During the first half of the seventeenth century the refracting telescope established itself as a vital and necessary adjunct of celestial observation. Kepler in 1611 suggested a telescope with a convex lens as eyepiece instead of a concave lens as in the Dutch and Galilean instruments, and Gascoigne showed its special adaptability to purposes of micrometrical measurement. It was soon discovered, however, that objects viewed through it were indistinct and

The reason of this is that every lens is a collection of prisms, and if we look through a prism we see everything fringed with the most brilliant hues. It is very beautiful to see these rainbow tints (and they hold a priceless secret in another direction); but when they make their appearance in the telescope the effect is most annoying.

The early observers tried hard, but without success, to eliminate these colours. They improved the eye-piece by making it of two lenses instead of one, and they improved the definition of the object-glass by lengthening its focus, thus increasing the size of the image whilst the breadth of the colour-fringe remained about the same. Hence the telescope grew in length to twelve, fifty, or a hundred feet; and one philosopher made an object-glass of 600 feet focus, of which we need not be surprised to learn that he was quite unable to make any use! These long-focal glasses were either placed in unwieldy tubes, managed from a mast with spars and tackle, or they were used without a tube at all, the observer being furnished with a long string with which he did his best to keep the object-glass square to the eye-piece. In either case the whole affair was awkward and cumbersome in the extreme, and it reflects the highest honour on Hevelius, Huyghens, Cassini, and the rest that, amid so many difficulties and annoyances, they were able to make the discoveries they did. Looking for

a needle in a haystack is child's play to their troubles.. A few of these old telescopes and lenses are still in existence, and a famous object-glass of 123 feet focus, that belonged to Huyghens, is preserved in the museum of the Royal Society. But no English-made telescope older than Newton's time is known to exist, though there must surely be one or two hidden away in the lumber-rooms of colleges or mansions.

This loss is all the more to be regretted because we have the authority of Prof. Grant for saying that "in England the construction of telescopes seems to have attained considerable perfection at a comparatively early period." An English-made telscope magnifying 100 times was placed in the Copenhagen Observatory when it was established in 1656. "The telescope of Sir Paul Neile, as well as those of Reeves and Cox, are said to have been equal to the best telescopes executed at the same time in any country of Europe." William Ball, with a telescope of 38 feet focal length, made in Devonshire in 1665 what was long thought to be the discovery of the division in Saturn's ring. Bradley employed telescopes up to 212 feet focus, and with the last mentioned object-glass measured the diameter of Venus.

Copernicus vindicated.

Although the seventeenth century saw no further improvement in the refractor beyond what we have described, great strides had

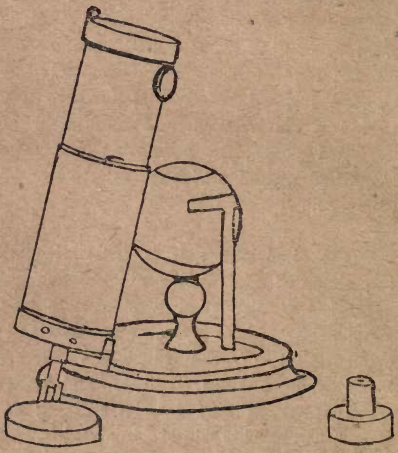
been made compared with the results of Galileo's day. For one thing the truth of the Copernican hypothesis had been abundantly confirmed. Much had been learnt about both Sun and Moon; the cloud-belts of Jupiter and the spots on Mars had begun to be studied; the mystery of Saturn's ring had been more fully solved; four of his moons discovered; and, in short, the known wonders of the heavens multiplied a hundredfold. Though still in its awkward youth, the refracting form of telescope had reaped a rich harvest in the depths of space.

But a rival was now to enter the field in the shape of the Reflecting Telescope. The year that Galileo died a child was born in Lincolnshire whose fame was destined to eclipse that of the illustrious Florentine. Puny when a babe, delicate and backward when a boy, a kick from a bullying schoolfellow awoke his slumbering genius. That kick was historic! The boy who was not strong enough to give his persecutor the thrashing he deserved found he could beat him at his studies. So

ISAAC NEWTON

climbed up the intellectual ladder, to become one of the mightiest intellects of all time, whose radiant genius was destined to place the topstone on the Copernican system and make plain to the world the mystery of gravitation.

"Nature and Nature's laws lay hid in night.
God said, 'Let Newton be!' and all was light!"



NEWTON'S REFLECTOR.

Sir Isaac Newton attacked the colour-problem of the refractor without being able to solve it; but he invented and made a telescope on the reflecting principle which, though only a few inches long, dealt in a surprising way with some of the easier objects in the heavens. A larger telescope of his construction is still preserved by the Royal Society. The principle of the reflector is briefly this. Instead of an image

being formed by transmission through an object-glass, it is formed by reflection from a concave mirror, which is then magnified by an eye-piece as in the case of the refractor. There are several kinds of reflector—one called the Newtonian after our illustrious philosopher; another the Gregorian after Gregory, a Scottish scientist, a relative of the inventor of that old nursery physic, "Gregory's powder"; a third the Cassegrainian, after the celebrated Frenchman who contrived it; and yet a fourth, the Herschelian, after Sir William Herschel, though invented by Le Maire in 1728. Of these the Gregorian reflector has had a certain vogue in its time, but is less appreciated to-day than its high merits deserve. The Gregorian was developed in the eighteenth century by Hadley and Short, who brought it to a commendable pitch of excellence.

But now another light was to dawn in the astronomical firmament. If anyone had visited Bath in 1766, gone to the modest lodging of a German music-teacher there, and pointed him out as a man destined to immortal fame, the world would have indulged in the luxury of a grin. But the world would have been wrong, for the music-teacher was

WILLIAM HERSCHEL,

and already he had picked up a small telescope, with which he was making his first

acquaintance with the wonders of the heavens What he saw with this instrument fired him with an ardent passion for Astronomy. Like Newton, the young man evinced great mechanical aptitude. As a German it goes without saying that he was industrious and thorough. In fact he was a prodigy of application. He determined to polish his own mirrors and construct his own telescopes. By 1781 he had succeeded so well as to discover the planet Uranus. The scientific world was incredulous, then jealous, and at length it hailed William Herschel as one of its brightest ornaments. George III., who loved science although he was a pig-headed ruler, made the young German his private astronomer, and placed him in such a position that he could proceed unhindered with his instruments and his observations.

Herschel's efforts were stupendous. In his vocabulary there were no such words as "failure" and "fatigue." Sometimes when polishing and testing his mirrors he worked incessantly for twenty-four hours at a stretch, and the food had to be placed in his mouth whilst he laboured at his delicate and difficult task. In 1789 he had constructed at Slough a mighty telescope, of which the great mirror was four feet in diameter and the tube 40 feet long. This in its day was the wonder of the scientific world. As Newton was a prince amongst mathematicians, so Herschel was a prince amongst observers. He taught mankind something of

the awful, the fathomless abysses of the universe, and made vast strides towards the elucidation of its mechanism. And he left the reflecting telescope far away in advance of its rival.

We cannot leave Sir William without saying a word about his sister. To

CAROLINE HERSCHEL

is due no doubt a considerable share of his success. That devoted woman was his right-hand supporter. She controlled for many years his domestic arrangements, and acted as his amanuensis, took notes for him whilst he was observing, and afterwards arranged his observations. However inclement the weather, there she was by the telescope doing her patient part. On one occasion a sharp projecting iron wounded her severely; yet she would not cry out lest she should disturb her brother and spoil his work at a critical juncture. So noble a life of devotion and self-effacement is not often to be met with, and when we hear talk of the intellectual inferiority of women we smile as we think of the services to science of Caroline Herschel, of Mary Somerville, of Agnes Clerke, of Lady Huggins, and of Madame Roberts. Names like these shine as stars in the firmament of celestial research.

Returning now to the refracting telescope, we find it at the middle of the 18th century a long, awkward thing, much as it was in the hands of Huyghens and Cassini. But an

Essex squire, named Chester More Hall, took up the colour question, and with such success that he was able to produce an object-glass which showed practically no colour—that was, in other words, achromatic. He did this by combining lenses of various kinds of glass, instead of the single lens which had hitherto been used. Strange to say, Hall took no steps to secure this great discovery for himself. Then came

JOHN DOLLOND,

a London optician, who independently attacked the problem, and with brilliant success. We cannot deal here with the details of the achromatic; suffice it to say that, thanks to the new combination, a teleseope three or four feet long was found capable of doing all that had been done by the ungainly refractors of the past.

Still, the reflector had the advantage, because Dollond found it impossible to procure suitable glass for his lenses of more than three or four inches in diameter. He had the skill, but the requisite material was not forthcoming. The little achromatic so far as it went was all that could be desired; but still the reflector was in advance.

Here again, however, the hour and the man had come. Once more we are to behold the true democracy of science. She knows no caste or class. With her position is nothing: brains count as everything. A Swiss artisan —Guinand by name—turned his attention to

the making of spectacles and afterwards of telescopes. It became his ambition to increase the size of the achromatic. Seven years he toiled and laboured, but without success. Seven years is a long time to battle with failure, and an ordinary man would have given up the contest. But Guinand was no ordinary man. He redoubled his efforts, spent every penny of his earnings on experiments, reduced himself and his household to beggary. And then, at last, after fifteen years of unremitting toil and bitter adversity, he triumphed—he had gained the secret. Guinand was one of the heroes of science, and very nearly proved one of its martyrs. He was able before his death to produce perfect discs of glass no less than eighteen inches in diameter. Guinand died; but his secret was handed on. Continental discontent drove its owner to England, and it is now in possession of that great firm of glass-founders, the Messrs. Chance. So it came about that by 1829 a 12-inch achromatic of great perfection had been constructed, and the race between reflector and refractor was renewed in good earnest.

It must not be thought for a moment that the reflecting telescope—giant though it was—had reached its meridian. Up to 1845 Herschel's four-foot reflector was the largest ever constructed. In that year, however, a gifted Irish nobleman, who had already polished and mounted a three-foot mirror, astonished the world with one six feet in

diameter. In those days lords who devoted their treasure and their talents to the advancement of science were fewer even than they are at present. But

LORD ROSSE

towered above his peers just as his immense reflector towered above all others. He was a man of splendid mechanical ability. More than this, he was a born leader of men, for he trained up unlettered peasants on his estate to assist in the grinding, polishing and mounting of his gigantic mirrors. The Rosse telescope at Parsonstown is still in existence, and at one time it was in charge of Sir Robert Ball, to whose lucid lectures we have many of us had the pleasure of listening. The tube of this grand telescope is 56 feet long, and seven feet in diameter. A tall man could walk through it, holding an open umbrella above his head! The great mirror alone weighed four tons, and many were the anxieties and failures before it was successfully completed.

It is matter for national pride that, whilst the refracting telescope came to us from the Continent, the Achromatic and the Reflector are both of British origin. The names of nearly all those connected with the inception and development of the Reflecting Telescope are English, using that word in its best and widest sense. Newton, Gregory, Hadley, Short, Herschel, Rosse and Lassell are illustrious names; and to them must be

added, in our own time, With, Calver, Common, and Grubb. In the hands of the first three the silvered glass mirror—though a French invention—replaced the metal speculum of the older makers, and has advanced to the highest reputation. The late Dr. Common, of Ealing, brought his labours to a close with a reflector of 5 feet aperture, which was, and perhaps still is, the most powerful telescope in the world. So intense is the light-gathering power of this mirror that to glance through it at the full moon is to blind the eye for that night at any rate; and it is impossible to look at Sirius or even at Jupiter without inconvenience. This splendid instrument, which is now in the United States, has special interest for people in Wales because Dr. Common's assistant at the time the great telescope was made was Mr. Albert Taylor, F.R.A.S., an astronomer of great ability, now one of His Majesty's Welsh Inspectors of Schools. As a matter of fact, Mr. Taylor was the maker of the great mirror, and it is a gratification to us all that his handiwork and that of Dr. Common is now in an atmosphere where its superb powers can be utilised to their best advantage.

The mention of America comes in most appropriately here. Up to forty or fifty years ago the refractor of ten or a dozen inches in diameter was considered a prodigy of its class, though necessarily far behind the great reflectors of which we have been speaking. But now light was to break upon the

subject—light from across the water. From the time that an American artist,

ALVAN CLARK,

helped his little boy to make a small telescope, the United States was destined to a commanding place in the great forward movement. We have seen how the merest accidents exercised a profound influence in the development of the telescope. The amusement of helping his boy set Alvan Clark seriously to work, and the result is seen to-day, not only in numerous beautiful instruments of moderate size, but in such mammoth refractors as those of Mount Hamilton and Chicago.

Here our own country has perforce to take a secondary place. Why? Through lack of ability or enterprise? Hardly, while we have our Grubbs and Calvers, our Cookes. Commons, Taylors and Wrays! No; the answer has to be sought elsewhere. One reason is the lack of Governmental and

THE YERKES OBSERVATORY, U.S.A.

private munificence as compared with the United States. The British Government (and remember that this is not a party matter) is deplorably behind hand where science is concerned. And our wealthy men are not much better. In the States there is always some millionaire like Yerkes to back up the scientist in the most liberal manner. Science in the States has only got to ask. American largemindedness and bounty have placed the worker on a pedestal where his British colleague regards him with envy and admiration.

But this is not the only reason why England, the home of the reflector and the achromatic, the home of Newton and Herschel and Adams, and many an illustrious astronomer, must henceforth take a secondary place. No! the secret is found in

OUR MISERABLE ATMOSPHERE,

so often foggy, misty, overcast, and even when apparently clear—disturbed and quivering in the telescope. English air is bad on the whole, especially towards the west; Welsh air is worse, Irish air worse still—another Irish grievance, though not our fault this time! This trembling and quivering is not particularly obvious in small telescopes, but in large ones it is simply ruinous. To erect a 36-inch refractor like that at Mount Hamilton on Penylan Hill, Cardiff, for example, would be to reduce it to impotency. The air at Penylan is as a rule not good

enough even for our 12-in. city reflector. Under such circumstances large apertures and high powers are simply thrown away. But it is not so everywhere. In Egypt, in Jamaica, in South America and in the Western States the atmosphere is by comparison exquisitely pure, and in such localities, and only such, can a great telescope put forth all its powers to the utmost advantage.

Fifty years ago an achromatic of a foot aperture was reckoned a marvel; but thanks to the efforts of the Clarks and to the perseverance of other makers, that record has long been left behind. Not 12 inches, but 30, are now considered a large size, and there are several refractors which outstrip even that. One of them is the 36-inch telescope at Mount Hamilton; the other, and the largest, the 40-inch refractor at the Yerkes Observatory, near Chicago. Now comes the question—are these giants to go on thus increasing in size? The answer at present seems to be in the negative, and for two reasons. In the first place because the giant object-glass absorbs a disproportionate quantity of light; in the second place because as it can only be supported at its edge the huge lens, weighing many hundreds of pounds, has a tendency to bend with its own weight. The bending of course destroys its figure and its usefulness. These difficulties do not apply with anything like such force in the case of the reflector, and therefore it is to the reflector

we have probably to look as the mammoth of the future. Up to late years the Americans thought nothing of the reflector—they had judged it before trying it. Then the Common 3-foot and 5-foot went over there, and Uncle Sam changed his mind, and he is now building a reflector that will leave even the great Rosse telescope completely in the shade.

Telescopes are used for various purposes. Mounted and fitted in a particular manner, they are powerful aids in ascertaining terrestrial positions, maintaining time standards with the utmost accuracy, and so ensuring the safety of navigation, as well as the regulation of the calendar. This is the most important work done at the great national observatories like those of Greenwich, Paris and Washington. Our royal observatory at

GREENWICH

was founded, Aug. 10, 1675, by Charles II. It was one of the wisest acts that monarch ever did. Everybody in those days believed that human affairs were influenced by the stars. The first astronomer-royal, Flamsteed, deliberately chose an auspicious hour for the foundation of the observatory, and a scheme of the heavens for that hour drawn by his own hand is still preserved at Greenwich. Whether there be anything is astrology or no, at all events Flamsteed's choice of an auspicious hour has stood the test of 230 years. During the whole

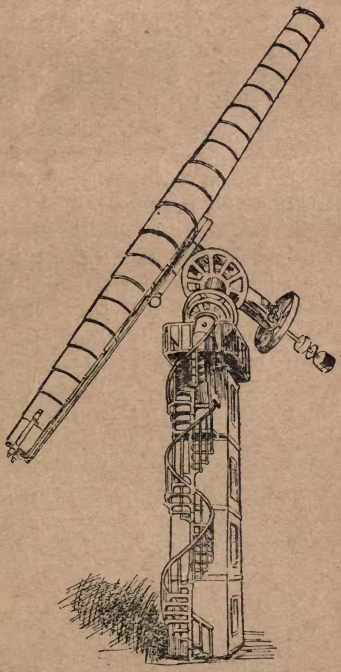
of that long period Greenwich observatory has done for the nation useful, beneficent and honourable work, and those who want to know all about it cannot do better than read Mr. Maunder's popular work upon the subject, the most interesting record of an observatory that was ever written. The stars have indeed smiled upon Greenwich. Some years ago a maniac climbed the hill with a bomb under his arm. He intended to wreck the observatory. But Flamsteed's choice

THE ROYAL OBSERVATORY, GREENWICH.

stood even this test. The bomb burst, but it was the maniac who was blown to atoms.

The routine work of Greenwich and the other national observatories is hard and onerous. But there are observatories whose telescopes are adapted for other and more picturesque purposes—for surveying the heavens, making discoveries, and checking those already made. Armed with the spectroscope, the telescope analyses the chemical

composition of the heavenly bodies. Armed with the photographic plate, it secures marvellous pictures of sun, moon and stars,



The Yebkes Refractor.

nebulae, comets, and even of meteors. In this connection I cannot omit to notice the work done by that great Welshman, the late

Dr. Isaac Roberts. A self-made man, he amassed a fortune and applied it and his great mechanical ability to sidereal photography, the outcome of which is seen in the two splendid volumes he had published e-fore his lamented decease.

To carry out the tasks to which I have alluded taxes the utmost refinements of optical and engineering skill, and the results would have been deemed miraculous only a few years ago. Work of this class is carried on at the Lick observatory on Mount Hamilton in California, a hill higher than Snowdon. It was founded by an eccentric millionaire named James Lick, and his ashes rest beneath the pier of the great telescope: the instrument alone cost over £20,000. Another such observatory is that near Chicago, endowed by the late Mr. Yerkes. Its telescope I have already mentioned. Yet another observatory is on Mount Wilson, where an enormous reflector is being erected for the study of the Sun. Another such instrument is that at Flagstaff, Arizona, under the direction of Mr. Percival Lowell.

Magnifying Power.

Very erroneous ideas are entertained as to the powers of telescopes. Great as these are, it is still impossible to talk with the engineers who (according to the sensational press) are digging the canals of Mars, or to count the hairs of the whiskers of the man

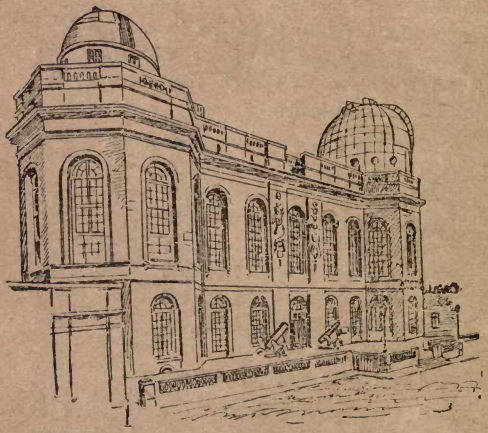
in the Moon! Powers much exceeding 1,000 are seldom employed on any telescope, and the Moon, for instance, is never seen more plainly than she would be if a couple of hundred miles away. A table drawn up on this basis of comparison is very instructive, giving at a glance the least distance to which we can apparently bring the heavenly bodies. Of course, it is only roughly approximate; still, it has its lessons. A telescope magnifying 500 times will show the various objects as though they were at the distances subjoined:—

The Moon	500 miles.
Venus	50,000
Mars	70,000
The Sun	200,000
Jupiter	800,000
Saturn	1,600,000
Uranus	3,000,000
Neptune	5,000,000
The nearest Fixed Star	50,000,000,000

If it were possible to make a telescope so powerful that the Moon would be brought within a mile of us, Mars in the same instrument would still seem 140 miles off; the Sun 400 miles; Jupiter 1,600; and the nearest fixed star 100,000,000 miles!!

Figures like these help us to realise the enormous magnitude of the universe. I should be sorry, however, if they discouraged the beginner, or turned him from expecting

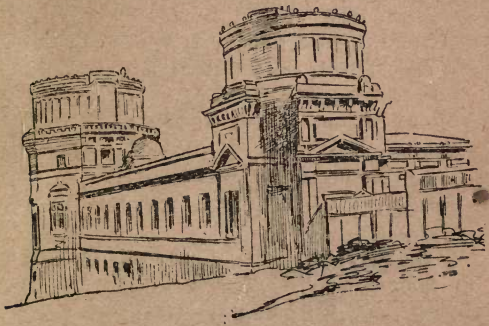
too much to the equally erroneous attitude of expecting nothing at all! Let him not imagine that even a small telescope is valueless, always providing it is good. Giant telescopes are usually employed for special purposes. For other things a moderate or even a small telescope would serve equally as well, and "the man at the small end"



THE NATIONAL OBSERVATORY, PARIS.

is another factor! Perfection in an instrument is as important as size. A small telescope if good will keep its possessor employed for many a long evening I look forward to the day when every school, yes, and every home, will have such a telescope in use. Even the price to-day

is not exorbitant. For two guineas Mr. Fletcher Burnerd, of Putney, supplies a 2-inch refractor that a few years ago you could not have purchased for five times the money. It is therefore not cost that makes the heavens a sealed book to so many to-day. My advice to those who want to begin is to consult Mr. Burnerd, and after you have learnt all that his instrument can teach you, get a Watson refractor or a Calver reflector, or if you prefer Welsh work, go to Mr. Ernest Madge, of Morriston, who will make you a reflector that will give you pleasure for the rest of your life.



ROYAL OBSERVATORY, EDINBURGH.

The World's Great Telescopes.

(IN ORDER OF APERTURE.)

The great telescopes of the world down to and including those of 20 inches aperture. Refractors are designated R; reflectors of speculum metal M; silvered glass reflectors S. Aperture, maker and also date are given where possible. An asterisk indicates that the instrument is now dismantled.

Mount Wilson, California.—8 foot, S; Ritchey; in course of construction.

Birr Castle, Ireland.—6 foot, M; Earl of Rosse; 1845.

Harvard, U.S.—5 foot, S; A. A. Common and Taylor; 1888; erected at Ealing; purchased by Harvard, U.S.A.

Mount Wilson.—5 foot, S; Ritchey.

London (?).—50 inch, S; Calver; constructed for the late Sir Hy. Bessemer.

*Slough.—4 foot, M; Wm. Herschel, 1789; dismantled 1840.

Melbourne.—4 foot, M; Grubb; cost £14,000; 1870.

Paris.—4 foot, S; Martin; £9,500; 1875.

*Malta.—4 foot, M; Lassell; 1861.

Meudon.—40 inch, S; Henry.

Paris Exhibition.—47 inch; Mantois; tube 200 ft.; 1900.

Chicago, Williams Bay.—40 inch, R; Alvan Clark; gift of C. T. Yerkes; 1897.

Birr Castle.—3 foot, M; Earl of Rosse; 1839.

Mount Hamilton, California.—37 inch, S; A. A. Common; removed from Ealing to U.S., 1895.

Mount S. Cristobel, Santiago.—37 inch S.

Mount Hamilton.—36 inch R; Clark; gift of James Lick; cost over £20,000; 1888.

South Kensington.—36 inch, S; Common.

Mount Hamilton.—33 inch; Clark; photographic.

Toulouse.—33 inch, S.

Meudon.—32 inch, R; Henry, 1891.

Marseilles.—32 inch, S; Foucault.

La Plata.—32 inch, S.

Potsdam.—31 inch, R; photographic, Steinheil; 1899.

Helwan, Egypt.—31 inch, S; Reynolds.

Allegheny.—30 inch, S.

Nice.—30 inch, R; Henry, 1889.

Poulkowa, Russia.—30 inch; R; Alvan Clark; 1882.

Greenwich.—30 inch R; Grubb; 1897.

Paris.—29 inch R; Martin.

Berlin.—28 inch, R; Steinheil.

Greenwich.—28 inch, R; Grubb, 1894.

Hastings-on-Hudson.—28 inch; Draper.

Vienna.—27 inch, R; Grubb, 1878.

Greenwich.—26 inch, R (donor, Thompson); photographic; 1897.

Washington.—26 inch, R; Clark; £9,000; 1871.

Charlottesville, U.S.—26 inch, R; Clark; 1874.

Meudon.—24 inch, R; Henry; photographic; 1891.

Cambridge.—25 inch, R; Cooke; originally erected at Gateshead in 1869; removed to Cambridge 1891.

Arequipa.—24 inch, R; 1896 (Bruce).

Edinburgh.—24 inch, R; Grubb.

Cape of Good Hope.—24 inch, R (McClean).

Oxford.—24 inch, R; photographic; Grubb, 1902.

Chicago.—24 inch.

Daramona.—24 inch, S; Grubb.

Flagstaff, Arizona.—24 inch; 1895.

*Malta.—24 inch, M; Lassell; 1844; now at Greenwich.

Paris.—24 inch, R; equatoreal coude; Henry; 1891; photo and visual.

Princeton, U.S.—23 inch, R; Clark; 1881.

Mount Etna.—22 inch, R; Merz.

Edinburgh, Calton Hill.—21 inch.

Buckingham (?).—22 inch, R.

Porro, Italy.—20½ inch, S.

Denver.—21 inch, R; Fauth; 1891.

Algiers.—20 inch, S.; Foucault.

Manila.—20 inch, R; 1892.

Potsdam.—20 inch, R; Steinheil.

Glasgow.—20 inch, S; Grubb.

*Hammerfield.—20 inch, M; Nasmyth.

*Crowborough.—20 inch, S; Grubb.

Some Famous Observatories.

Some of the world's famous observatories, compiled (with additions and corrections) from "Les Observatoires Astronomiques et les Astronomes," issued under the direction of Professor Dr. Stroobant, of Brussels. Dr. Stroobant's invaluable work should be in the hands of everyone practically interested in astronomy.

BRITISH ISLES.

GREENWICH.—The Royal Observatory. Founded 1675. First Astronomer Royal, Flamsteed. Present (eighth) holder of the office, Sir W. H. M. Christie. Eight assistants and 10 calculators. The "Nautical Almanac" is controlled by Dr. A. M. W. Downing with nine assistants. Founded 1767.

EDINBURGH.—Royal Observatory; 1818, transferred to Blackford Hill 1896; director, F. W. Dyson; three assistants, one calculator.

DUBLIN (Dunsink).—Royal Observatory, 1782; director, E. J. Whittaker.

Armagh, 1790.—Founded by Robinson.

Bidston, Liverpool, 1843.—W. E. Plummer.

Birr Castle, Ireland, about 1840.—Founded by the third Earl of Rosse; director, Dr. Boeddicker. Has the famous 6ft. and 3ft. reflectors.

Cambridge, 1820.—University Observatory; Sir R. Ball.

Daramona, 1881.—W. E. Wilson.

Darlington, Tow Law, 1885.—Rev. T. E. Espin.

Dunecht.—Earl of Crawford. Now dismantled.

Durham, 1841.—University Observatory; director, Sampson.

Edinburgh, Calton Hill, 1776.—City Observatory; director, W. Peck.

Glasgow, 1760.—University; director, L. Becker.

Halifax, 1878.—Founded by late E. Crossley.

Kew, 1842.

Lyme Regis, Rousdon, 1884.—Founded by late Sir Cuthbert Peek; director, Chas. Grover.

Markree, 1824.—Founded by Colonel Cooper.

Oxford.—Radcliffe Observatory, 1771; director, A. A. Rambaut. University Observatory, 1873; director, H. H. Turner.

Rugby, 1871.—Temple Observatory; G. M. Seabroke.

South Kensington, 1875.—Solar Physics Observatory; director, Sir Norman Lockyer; Astrophysical laboratory; director, A. Fowler.

Stonyhurst, 1838.—Jesuit College; Fathers Sidgreaves and Cortie.

Sunderland, 1857.—T. W. Backhouse.

Tulse Hill, London, 1866.—Sir W. Huggins.

Besides the above there are numerous private observatories where much valuable work is done, as those of Messrs. Backhouse (Sunderland), Scriven Bolton (Leeds), Buss (Manchester), Brook (Meltham), Denning (Bristol), Dennett (London), Gore (Dublin), R. C. Johnson (Birkenhead), Rev. R. Killip (Withington),

Longbottom (Chester), McEwen (Glasgow), Colonel Markwick (Boscombe), McHarg (Lisburn), Maw (Kensington), Newbegin (Sutton), Rev. T. E. R. Phillips (Ashtead), Saunder (Crowthorne), Miss Stevens (Oxford), Stanley Williams (Brighton), &c., &c. There are also a number of public and quasi-public observatories, including Cardiff (12-inch reflector, the gift of Franklen Evans); Paisley (Messrs. Coates); Sheffield; Southport (Baxendell); Manchester; Leeds (Duncombe), &c.

COLONIAL AND FOREIGN.

Algiers.

Allegheny, 1859.

Athens, 1843.

Arequipa, Peru.—Branch of Harvard.

Berlin.—Koenigliche Sternwarte, 1832; H. Struve. Urania, 1888. Treptow, 1896.

Bogota, 1803.

Bologna, 1712.

Bonn, 1845.—Kustner.

Bothkamp, 1870.

Breslau, 1790.—Franz.

Brussels, Uccle, 1829.

Cape of Good Hope, 1820.—Royal Observatory. Director, Hough.

Cambridge, Harvard, U.S., 1840.—Director, E. C. Pickering; four astronomers and 40 assistants.

Charlottesville, 1882.—Leander McCormick Observatory.

Chicago, Williams Bay, 1892.—Yerkes Observatory.

Christiania, 1833.
Cincinnati, 1843.—Founded by O. M. Mitchell. Removed to Mount Outlook 1873.
Coimbre, 1792.
Copenhagen, 1637.
Cordoba, Argentine, 1870.
Denver, 1890.—Chamberlin Observatory.
Durban, 1882.
Echo Mountain, 1894.—E. C. Larkin.
Flagstaff, Arizona, 1894.—Percival Lowell.
Geneva, 1772.—Gautier.
Geneva, U.S.A.—W. R. Brooks.
Goettingen, 1751.—Founded by Tobias Mayer Gauss was a subsequent director.
Hamburg, 1825.—Schorr.
Heidelberg, 1762.—Valentiner. Astrophysical, 1877.—Wolf.
Helwan, Egypt, 1904.
Jena, 1812.
Jouriew (Dorpat), 1809.
Juvisy, 1883.—Camille Flammarion.
Jaipur.—Maharaja's observatory (one of several remarkable native establishments).
Kasan, 1833.—Doubiago.
Kiel, 1874.—Kobold.
Koenigsberg, 1811.
Leipzig, 1787.
Lisbon, 1861.
Lovedale, South Africa, 1891.—A. W. Roberts.
Lussinpiccolo, 1893.—Leo Brenner.
Lyons, 1878.
Madras, 1792.—Director, C. Michie Smith.
Marseilles, 1702.
Melbourne, 1853.—Baracchi.

Meudon, 1876.—Founded by Janssen.

Milan, 1763.—Schiaparelli was many years director.

Mount Hamilton, California, 1875.—Founded by James Lick. Director, W. W. Campbell. Branch at Santiago.

Mount Wilson, California, 1904.—Solar physics (Carnegie Institute). Director, G. E. Hale.

Munich, 1818.

Nice, 1881.—Founded by Bischoffsheim.

Northfield, U.S., 1877.—Director, W. Payne.

O-Gyalla, 1871.—Von Konkoly.

Padua, 1767.

Palermo, 1790.

Paris, 1667.—National Observatory.

Parma, 1759.

Perth, Western Australia, 1897.—W. E. Cooke.

Pic du Midi, 1873.

Potsdam, 1874.—Astrophysical.

Poulkova, 1839.

Prague, 1751.—K. K. Sternwarte. Director, L. Weinek.

Princeton, 1866.

Rio de Janeiro, 1827.

Rome, Roman College, 1776.—Father Secchi was a former director. Vatican Observatory, founded by Pope Gregory XIII. University Observatory, 1827.

St. Petersburg, 1883.

San Fernando, 1793.

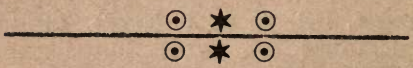
Stockholm, 1748.

Strasburg, 1872.

Sydney, 1827.—H. A. Lenehan.

Toulouse, 1839.

Turin, 1791.
Upsal, 1744.
Vienna, 1735.
Washburn.
Warner.
Washington, 1843.—U.S. Naval Observatory.
Windsor, N.S.W., 1874.—J. Tebbutt.



Some Astronomical Landmarks

Appended is a list, compiled from many and various sources, of dates which represent the progress of astronomy since the invention of the telescope. Of course, the chronology is a very imperfect one: to do it full justice would need a small volume. The items, however, suggest the opening out of research in various directions. Amongst them are included—erection of large instruments, establishment of observatories, foundation of societies, issue of well-known books, and deaths of eminent astronomers.

1543 Death of Copernicus; his work, suggesting the true theory of the solar system, was published the same year.

1601 Death of Tycho Brahe.

1608 Lippershay constructs the first telescope, with concave eyepiece.

1609 Galileo constructs one with which he observes the heavens.

1610 Harriot introduces the telescope into England. Galileo announces his discoveries.

1621 Death of Harriot.

1630 Father Scheiner uses the convex eyepiece. Death of Kepler.

1631 Mercury first seen in transit.

1639 Horrox and Crabtree observe the first recorded transit of Venus.

1640 Gascoigne invents the micrometer.

1642 Death of Galileo. Birth of Newton.

1655 Death of Gassendi.

1656 Huygens announces discovery of Saturn's ring and first satellite.

1662 The Royal Society.

1663 Gregory invents the reflecting telescope bearing his name.

1664 Hooke discovers great spot on Jupiter.

1667 Paris Observatory.

1668 Newton invents the reflecting telescope bearing his name.

1671-84 Cassini discovers four of Saturn's moons.

1672 Cassegrain invents the reflecting telescope bearing his name.

1675 The Royal Observatory, Greenwich.

1679 Hevelius publishes the "Machina Celestis" containing a detailed account of his large telescopes. The "Connaissance des Temps."

1687 Newton's "Principia." Death of Hevelius.

1689 Roemer invents the transit instrument.

1695 Death of Huygens.

1705 Halley's "Synopsis of Cometary Astronomy."

1710 Death of Roemer.

1711 Berlin Observatory.

1712 Death of Cassini.

1719 Death of Flamsteed, 1st Astronomer Royal.

1722 Bradley measures the diameter of Venus with a telescope of 212 feet focus.

1723 Hadley constructs a Newtonian reflector of 6 inches aperture, with powers up to 230.

1724 Last total solar eclipse visible in England.

1725 St. Petersburg Observatory.

1727 Death of Sir Isaac Newton. Bradley discovers the aberration of light.

1729 Chester More Hall constructs an achromatic object-glass. Flamsteed's "Atlas Coelestis."

1731 Hadley invents the sextant.

1732 James Short begins to construct his improved reflecting telescopes.

1738 Birth of William Herschel.

1742 Death of Halley.

1758 John Dollond re-invents the achromatic object-glass.

1761 Transit of Venus. Death of Dollond.

1762 Death of Bradley and Mayer.

1763 The Brera (Milan) Observatory.

1765 Harrison rewarded by the Government for inventing the chronometer.

1767 The "Nautical Almanac."

1769 Transit of Venus.

1770 Lexell's Comet.

1771 Radcliffe Observatory, Oxford.

1774 William Herschel makes a 5-inch reflecting telescope. Berlin "Jahrbuch."

1776 Death of Ferguson and Harrison.

1781 Herschel discovers Uranus.

1783 Herschel makes an 18-inch reflector. Death of Euler.

1785 Dublin (Dunsink) Observatory.

1786 Death of Wilson.
1787 Vatican Observatory.
1789 Herschel completes his 4-foot reflector, and discovers two satellites of Saturn.
1790 Guinand discovers the secret of preparing flint glass.
1792 Madras Observatory.
1793 Bailly murdered under the French Revolution.
1796 Death of Rittenhouse.
1799 Laplace begins his "Mecanique Celeste." Great meteor shower.
1801 Piazzi discovers the first Planetoid.
1803 Herschel discovers binary stars.
1804 Death of Kant.
1805 Great meteoric stone falls at L'Aigle.
1813 Death of Lagrange.
1814 Koenigsberg Observatory.
1816 Death of Schroeter.
1817 Death of Messier.
1818 Edinburgh Observatory.
1820 Royal Astronomical Society. Cambridge Observatory.
1821 Cape of Good Hope Observatory. "Astronomische Nachrichten."
1822 Death of Sir William Herschel and Delambre. Paramatta Observatory.
1824 9-inch refractor erected at Dorpat. Lohrmann's map of the Moon.
1826 Vienna Observatory. Sir J. South erects a 12-inch refractor at Kensington (now at Dublin). Death of Fraunhofer, Bode and Piazzi.
1827 Death of Laplace.

1828 Death of Wollaston.

1831 Death of Pons.

1832 Death of Zach.

1833 Great meteor shower.

1838 Liverpool (Bidston) Observatory and Stonyhurst Observatory.

1839 Poulkowa Observatory. Lord Rosse constructs his 3-foot reflector.

1840 J. W. Draper takes the first celestial photograph. Glasgow and Harvard Observatories. Bessel determines parallax of 61 Cygni. Death of Olbers.

1842 Washington Observatory.

1843 Schwabe detects sunspot period. Cincinatti Observatory.

1844 Smyth's "Celestial Cycle." Electric time signals in United States. Death of Henderson and F. Baily.

1845 Bonn Observatory. Lord Rosse completes his 6-foot reflector at Parsonstown. British Association star catalogue.

1846 Neptune and its satellite discovered. Death of Bessel.

1848 Death of Caroline Herschel.

1849 John Herschel's "Outlines of Astronomy." Humboldt's "Cosmos."

1850 A star first photographed.

1851 Saturn's crape-ring discovered.

1852 Grant's "History of Physical Astronomy." "American Nautical Almanac."

1853 Death of Arago and Doppler.

1855 Loomis's "Practical Astronomy." Death of Gauss.

1856 Steinheil suggests silvered glass for telescope mirrors; Foucault does so independently the following year.

1857 Death of Thos. Dick.

1858 Photoheliograph erected at Kew. Comet (Donati's) first photographed.

1859 Kirchhoff unravels the secret of the spectrum lines. Webb's "Celestial Objects." Mrs. Ward's "Telescope Teachings." Allegheny Observatory. Death of W. C. Bond, Nichol and Olmsted.

1860 Photography used successfully at solar eclipse. Kirchhoff's map of the solar spectrum.

1861 G. F. Chambers' "Handbook of Astronomy." Lassell erects 4-foot reflector at Malta. Earth passes through Comet's tail.

1862 Alvan Clark discovers the companion to Sirius. Death of Mitchel.

1863 William Huggins begins his spectroscopic researches. The Bonn Durchmusterung. "Astronomical Register."

1864 Death of Plana and W. Struve. Comet first spectroscopically studied.

1865 Proctor's "Saturn." "English Mechanic." Death of W. H. Smyth and Encke.

1866 Supposed change in lunar crater Linne detected. Great meteor shower. New star in Corona.

1867 Cooke constructs 25-inch refractor for R. S. Newall. Death of South and Lord Rosse.

1868 Solar prominences observed by Norman Lockyer, and by Janssen independently. Lockyer's "Lessons in Astronomy." Death of W. R. Dawes, Foucault, and Brewster.

1870 Proctor's Star Atlas. Death of Miller.

1871 Death of Sir John Herschel.

1872 Death of Mrs. Somerville, Angstrom, Kaiser, and Delaunay.

1873 Greenwich begins daily photographs of Sun. Schmidt completes his great map of the Moon. Burnham's first double-star catalogue. Death of Donati.

1874 Transit of Venus. Potsdam Astrophysical Observatory. Death of Maedler and Hansen. Nasmyth's "Moon."

1875 Death of Argelander, Schwabe and Carrington.

1876 Neison's "Moon."

1877 Hall discovers satellites of Mars. Schiaparelli detects Mars' canals. Gill rectifies the solar parallax. "The Observatory." Death of Le Verrier and Heis.

1878 Death of Father Secchi and T. Grubb.

1879 Gould's Uranometria Argentina. Death of Clerk-Maxwell, Lamont and Boyden.

1880 Draper photographs the Orion nebula. Death of Lassell, Peirce, Watson and Peters.

1881 Common photographs the Orion nebula. Death of W. R. Birt and Dembowski.

1882 Death of H. Draper and Zoellner.

1883 Death of Schmidt, Dallmeyer and Sabine.

1884 International Conference accepts Greenwich as the first meridian. Death of Klinkerfues.

1885 Isaac Roberts begins nebular photography. New star in Andromeda. Death of T. W. Webb.

1886 Ball's "Story of the Heavens." Death of Oppolzer.

1887 International photographic survey of the heavens decided on. Lockyer's meteoric theory. Societe Astronomique de France. Death of Alvan Clark and Kirchhoff.

1888 Lick Observatory on Mount Hamilton founded. Young's "Astronomy." Death of R. A. Proctor.

1889 A. A. Common erects 5-foot reflector at Ealing. Death of Warren de la Rue, Loomis, Respighi, and of Father Perry while conducting an eclipse expedition for the Government.

1890 British Astronomical Association. Death of Peters and Nasmyth.

1891 Pickering begins lunar work at Arequipa. Denning's "Telescopic Work." Death of Schoenfeld and Brunner.

1892 Hale photographs the chromosphere on the solar disc. Death of Sir G. B. Airy, Adams and Rutherfurd. Barnard discovers Jupiter's 5th satellite. Flammarion's "Mars."

1893 Gore's "Visible Universe." Death of Pritchard.

1894 23-inch refractor erected at Greenwich. Lowell begins work at Flagstaff. Astronomical Society of Wales. Death of Helmholtz, Denza and Ranyard.

1895 Blackford Hill (Edinburgh) Observatory founded. Elger's "Moon." Death of Hind, Cayley, Kirkwood, Spoerer, and Trouvelot.

1896 Young's "flash" spectrum confirmed. Fowler's "Telescopic Astronomy." Death of Gylden, Tisserand, Gould, Winlock and H. A. Newton.

1897 The Yerkes 40-inch refractor completed. Death of Stone, Elger, Winnecke, A. G. Clark, Marth and Freeman.

1898 Planetoid Eros and 9th satellite of Saturn discovered. The "Indian" Eclipse; Mrs. Maunder photographs the outer corona. Death of Dunkin and Sadler.

1899 Sir Wm. and Lady Huggins' atlas of stellar spectra. Death of Bunsen.

1900 Great Telescope at Paris Exhibition. Death of Keeler and N. E. Green.

1901 Nova Persei. Death of Peek and Rowland.

1902 Death of Faye and Cornu.

1903 Pickering's "Moon." Death of Common, Prosper Henry and Stokes.

1904 Janssen's solar atlas. Death of Dr. Isaac Roberts, Captain Noble, Bredikhine, and Perrotin.

1905 Tenth satellite of Saturn; sixth and seventh of Jupiter. Death of O. W.

Struve, Paul Henry, Copeland, and S. J. Johnson.

1906 Death of Langley.

1907 Fauth's "Moon." Death of Miss Agnes Clerke, and A. S. Herschel.

1908 Burnham's great double-star catalogue. Comet Morehouse; remarkable photographic results. Eighth satellite of Jupiter. Death of Vogel, Janssen, Kelvin, Molesworth and Stuyvart.

1909 New ring of Saturn, observed at Geneva, confirmed at Greenwich.

Some Astronomical Societies.

(IN ORDER OF SENIORITY.)

Royal Astronomical Society, 1820; Burlington House, London.

Leeds Astronomical Society, 1859.

Astronomical Society of Chicago, 1862.

Astronomische Gesellschaft, 1865.

Liverpool Astronomical Society, 1881.

Societe Astronomique de France, 1887.

Urania, Berlin, 1888.

Astronomical Society of the Pacific, 1889.

British Astronomical Association, 1890.

Societe Astronomique Russe, 1890.

Royal Astronomical Society of Canada, 1890.

Astronomical Society of Wales, 1894.

Societe Belge d' Astronomie, 1895.

Astronomical Society of America, 1899.

Manchester Astronomical Society, 1903.

Astronomical Society of Newcastle-on-Tyne, 1904.

Wanganui (New Zealand) Astronomical Society, 1905.

Societe d' Astronomie d' Anvers, 1905.

Societa Astronomica Italiana, 1906.

Some Astronomical Periodicals.

(IN ORDER OF SENIORITY.)

Astronomische Nachrichten, Kiel, 1821.

Sirius, Cologne.

The Observatory (monthly), London, 1877.

Ciel et Terre, Uccle, 1880.

Bulletin Astronomique, Paris, 1884.

Astronomical Journal, U.S., 1851.

Popular Astronomy, Northfield, U.S., 1893.

Astrophysical Journal, U.S., 1895.

Astronomische Rundschau, Lussinpiccolo, 1899.

Important astronomical contributions also appear regularly in "Nature," "Knowledge, and the "English Mechanic." The services of these journals to British astronomy have been simply invaluable. Most of the astronomical societies have their special publications as the "Monthly Notices" of the Royal Astronomical Society, the "Journal" of the British Astronomical Association, the "Bulletin" of the Societe Astronomique de France, the "Cambrian Natural Observer" of the Astronomical Society of Wales, and the annual reports of the Leeds and Liverpool Astronomical Societies.

Works on Astronomy.

One is so often asked to recommend books on astronomy that I have been led to draw up a short list for the use of those entering on its study, with special reference to the observational side. Large numbers of works are available, but I can hardly do better than suggest the following, those specially adapted for beginners being distinguished by an asterisk. I have not included such purely elementary books as the charming volumes of Miss Giberne.

General Works.

Ball, Sir R.—The Story of the Heavens.

Chambers, G. F.—A Handbook of Descriptive Astronomy.

Flammarion, C.—Les Terres du Ciel.

Lockyer, Sir N.—Elementary Lessons in Astronomy.

Lynn, W. T.—Celestial Motions.

Todd, D. P.—Stars and Telescopes.

Young, C. A.—A Text-book of General Astronomy.

History and Biography.

Ball, Sir R.—Great Astronomers.

Clerke, Agnes M.—A Popular History of Astronomy during the 19th Century.

— The Herschels and Modern Astronomy.

Fahie.—Galileo, his Life and Work.

Maunder.—The Royal Observatory, Greenwich.

Macpherson.—A Century's Progress in Astronomy.

The Telescope and Observation.

Baikie, Jas.—Through the Telescope.

Denning, W. F.—Telescopic Work for Starlight Evenings.

Fowler, A.—*Popular Telescopic Astronomy.

Noble, W.—*Hours with a 3-inch Telescope.

Oliver, J. A. W.—Astronomy for Amateurs.

Proctor, R. A.—*Half Hours with the Telescope.

Webb, T. W.—Celestial Objects for Common Telescopes.

The Sun.

Ball, Sir R.—The Story of the Sun.

Proctor, R. A.—The Sun, ruler and life of the planetary system.

Young, C. A.—The Sun.

The Moon.

Elger, T. G.—The Moon, a full Description and Map.

Fauth, P.—The Moon in Modern Astronomy.

Mellor, T. K.—Handy Map of the Moon.

Nasmyth and Carpenter.—The Moon as Planet, World and Satellite.

Neison.—The Moon and the Configuration of its surface.

Pickering, W. H. —The Moon, a Summary and Atlas.

Porthouse, W.—*Map of the Moon.

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Proctor, R. A.—The Moon, her motions, aspects, and physical condition.

Planets, Comets, Meteors.

Chambers.—The Story of Eclipses.
Clerke, Ellen M.—The Planet Venus.
— Jupiter and his System.
Denning, W. F.—General Catalogue of Meteoric Showers.
Johnson, S. J.—Eclipses past and present.
Lynn, W. T.—Remarkable Eclipses.
— Remarkable Comets.
Flammarion, C.—La Planete Mars.
Lowell, P.—Mars.
Proctor, R. A.—Saturn and its System.

The Sidereal Universe.

Chambers, G. F.—*The Story of the Stars.
Clerke, A. M.—The System of the Stars.
Gore, J. E.—The Stellar Heavens.
Heath, T. E.—Our Stellar Universe: A Road-book to the Stars.
Roberts, Isaac.—A Collection of Photographs of Stars, Star Clusters and Nebulæ.

Naked Eye Astronomy, Calendars, and Charts.

Ball, Sir R.—A Popular Guide to the Heavens.
"Companion to the Observatory" (Annual).
Dunkin, E.—*The Midnight Sky.
Flammarion, C.—Annuaire Astronomique.
H. P. H.—*The Star Almanac (Annual).
"Knowledge" Year Book (Annual).

Klein, H.—Star Atlas.

Mee.—*Observation without Instruments.

—*The Heavens at a Glance (Annual).

Maunder, E. W.—*Astronomy without a Telescope.

Peck, W.—The Observer's Atlas.

Philips' Planisphere.

Proctor, R. A.—Star Atlas.

METEOROLOGY.

Chambers, G. F.—The Story of the Weather.

Horner, D. W.—Observing and Forecasting the Weather.

Inwards, R.—Weather Lore.

No notice has been taken of old but otherwise excellent books, such as Smyth's "Celestial Cycle," Dick's "Celestial Scenery," Mitchell's "Orbs of Heaven," and Mrs. Ward's "Telescope Teachings." An admirable set of star maps by Mr. Norman Lattey appeared some time ago in the "English Mechanic," also a valuable series of articles on variable stars by Colonel Markwick, a series on solar phenomena, another on practical spectroscopy, &c., &c. These were all eminently worthy of reproduction in book form.

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